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THUNDERSTORM FORECAST STUDY
for
EGLIN AFB, FL

by

Capt Daniel Cornell

MARCH 1993

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13. Abstract: This report describes the evaluation of an empirical technique (WINNDEX) for predicting air-mass thunderstorms at Eglin AFB, FL. Results showed that the WINNDEX objective forecast technique had a Heidke skill score of .18 in predicting thunderstorm activity on the Eglin Range complex. A discriminant analysis model was developed that improved this skill to .32 in predicting the occurrence of thunderstorms during four 3-hour periods beginning at 1200Z. The study demonstrates the utility of USAFETAC's lightning database in developing and verifying a thunderstorm forecast model for remote locations.

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PREFACE

This report documents the results of USAFETAC Project 920136, which was accomplished in response to a request from the 46th TW/DOW at Eglin AFB, FL. The requester asked USAFETAC to validate an empirically based forecast technique (WINNDEX) by comparing its performance to the actual occurrence of air-mass thunderstorms during the inclusive May to September time period.

In addition to validating the WINNDEX technique, USAFETAC developed two discriminant analysis models to:

- Predict when the first lightning strike will occur.

- Provide the probability of occurrence of thunderstorm activity during four 3-hour periods beginning at 1200Z.

Both these models were independently verified.

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1. INTRODUCTION

1.1 Background. The 46th TW conducts weapons testing over the large land and water ranges of Eglin AFB. F. ›m May to September, the predominant weather phenomenon affecting weapons testing operations is the air-mass thunderstorm. Because accurate thunderstorm forecasting is crucial to providing decision-makers the data needed to schedule weather-sensitive tests, Eglin staff meteorologist Mr Roger Winn (since retired) developed an empirically based technique to predict the timing (and, to some extent, the location) of air-mass thunderstorm activity at Eglin AFB. His technique (called "WINNDEX") is based on data collected for May through September of 1986. The if's, when's, and where's of predicting air-mass thunderstorms at Eglin AFB are influenced by moisture, stability and upper- and lower-level wind flows. Building on earlier techniques (Forsing, 1970), Mr Winn developed his WINNDEX to forecast sea-breeze thunderstorm development at Eglin AFB. Although WINNDEX has been used as a forecasting aid at Eglin AFB since 1987, its effectiveness has never been formally documented. This study was undertaken, then, to provide WINNDEX verification statistics for the months of May to September in the years 1986-1990. USAFETAC also developed discriminant analysis procedures to improve the timing in predicting the occurrence of thunderstorms on Eglin Main and on the Eglin Ranges. In both cases, the study showed the utility of using recorded lightning strikes to develop and verify a thunderstorm forecasting technique.

1.2 Components of the Study.

1.2.1 WINNDEX Validation. First, the WINNDEX convective forecast was compared against recorded lightning strikes and observed weather on days when the Showalter Index was less than 5 (the first WINNDEX criteria for convective activity). Second, forecast skill measures based on verification with recorded lightning strikes only were compared with verification based on recorded lightning strikes and surface observations.

1.2.2 Discriminant Analysis. Discriminant analysis procedures were used to:

- Classify observations based on the occurrence of the first lightning strike.
- Develop a model (discriminant function) that can be used to assign the probability of occurrence of thunderstorms on the Eglin ranges and at the Eglin aerodrome (Eglin main) during four 3-hour intervals beginning at 1200Z. These models were verified using an independent data set.

1.3 Data Sources. The data used in this study consisted of surface observations from Eglin AFB and nearby Hurlburt Field, upper-air observations from Eglin AFB and Apalachicola, FL, and recorded lightning strike data from the National Lightning Detection Network (Geomet Dynatec Inc, Tucson, AZ). The period of record for all datasets was from May through September, 1986-1990. Only weather occurring between the hours of 0600 and 2400Z was considered. Typically, both convective activity and flying operations drop off after 2400Z. On the days in which convective activity was expected throughout the day, 0600Z or local midnight was used as the start hour.

For purposes of verifying the WINNDEX, the entire dataset is considered independent even though the WINNDEX was developed using data from 1986. For the discriminant analysis, the data was separated into independent and dependent data sets.

Because of the limited number of lightning strikes during certain hours, the days to be used in the independent data set could not be selected totally at random. Therefore, 6 days of the month were selected to make up the independent data set so that for low lightning strike counts, about half the strikes would be included in the independent dataset. The dependent dataset is used to develop the discriminant models, which are then verified using the independent data set.

2. CLIMATOLOGY

2.1 Thunderstorm Distributions. For purposes of this study, thunderstorm activity, as indicated by recorded lightning strikes between the hours of 0600 and 2400Z, is stratified by upper- and lower-level winds. This wind stratification is the same as that used in the WINNDEX--that is, the 1200Z hour 2,000-foot (lower-level) wind is classified as *northerly* when the *v* (north-south) component is less than zero, and *southerly* when the *v* component is greater than or equal to zero. The mean direction of the winds at 12-16,000 feet (upper-level) is classified as *northerly* when the *v* component is less than or equal to zero, and *southerly* otherwise. The wind categories, then, are:

NN Both upper- and lower-level winds have a *northerly* component.

NS Upper- level winds have a *northerly* component; lower- level winds have a *southerly* component.

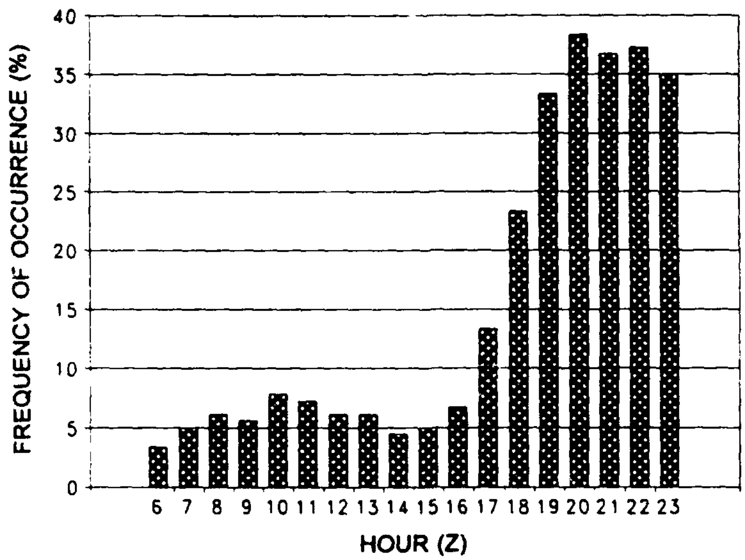
SN Upper-level winds have a *southerly* component; lower-level winds have a *northerly* component.

SS Both upper- and lower-level winds have a *southerly* component.

2.1.1 Hourly Distribution. Because of the size of the Eglin Range complex, the upper-level (steering) wind flow doesn't have much effect on the frequency of thunderstorm activity (as inferred from recorded lightning strikes--see Figures 1 & 2). However, the influence of the boundary-layer wind is apparent. With northerly boundary-level flow, a secondary peak in activity during early morning becomes apparent. This is the result of land-breeze activity moving onshore. This secondary peak is, of course, more evident with southerly steering winds. Southerly flow in the boundary layer at 1200Z indicates that the land breeze, if any, was weak and that the enhanced sea breeze will result in increased (and earlier) convective activity.

Although distributions for thunderstorm activity on Eglin Main (Figures 3 & 4) are similar to those for the Eglin Range, there are some pronounced differences. First, the secondary peak with northerly boundary-layer flow is not as evident, especially when the steering winds are out of the north. This is probably due to the fact that much of the convective activity dissipates as it moves onshore, resulting mostly in rain showers. Eglin Main is not large enough to pick up as many of the widely scattered thunderstorms that occur on the much larger Eglin Range. Also, when both the upper- and lower-level winds have southerly components, the peak activity occurs decidedly earlier in the day as the afternoon convective activity occurs farther inland--that is, north of Eglin Main.

2.1.2 Three-Hourly Distribution. For the purposes of developing a thunderstorm prediction model based on discriminant analysis, lightning strikes were binned into 3-hourly intervals. Figures 5-8 give the frequency of occurrence of at least one lightning strike during these 3-hour time periods for Eglin Main and the Eglin Ranges for each of the four wind stratifications. For comparison to the posterior probabilities determined using the discriminant function in calculation of the discriminant analysis model's Brier Skill Score, these occurrence frequencies are interpreted as climatological probabilities of occurrence.



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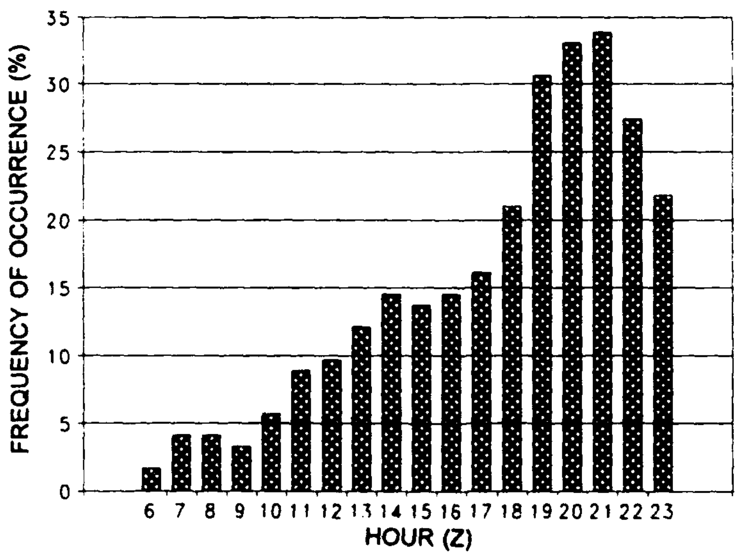
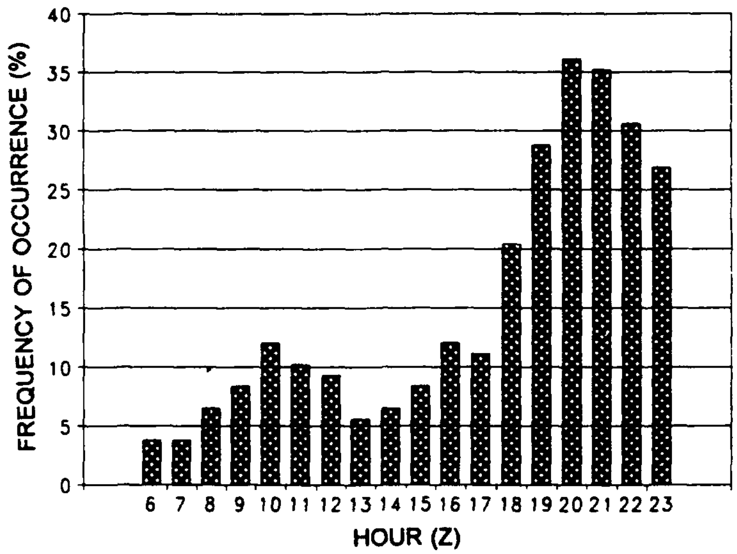


(b)

Figure 1. Frequency of occurrence of at least one lightning strike on the Eglin Range during indicated hour for May through September period when upper-level winds have a northerly component and lower-level winds have a northerly (a), southerly (b) component.



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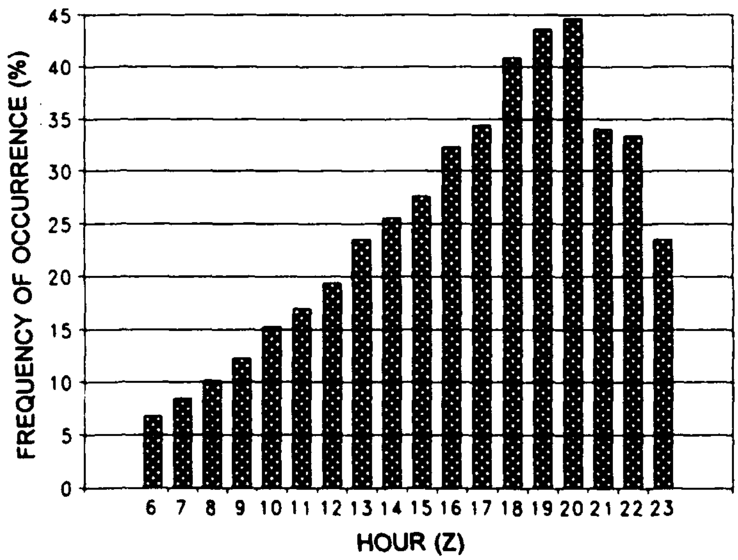

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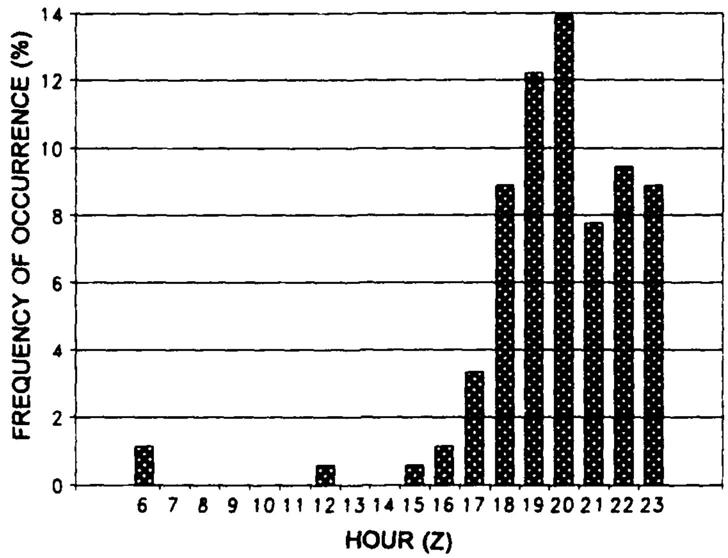
Figure 2. Frequency of occurrence of at least one lightning strike on the Eglin Range during indicated hour for May through September period when upper level winds have a southerly component and lower level winds have a northerly (a), southerly (b) component.



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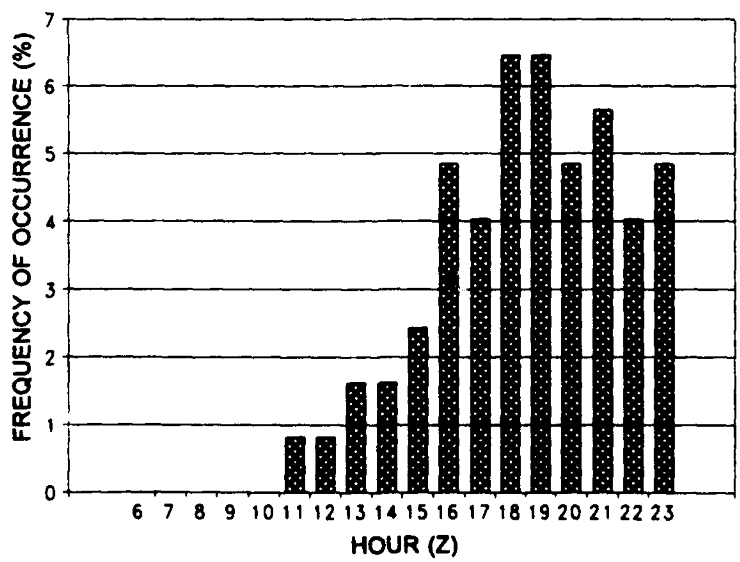
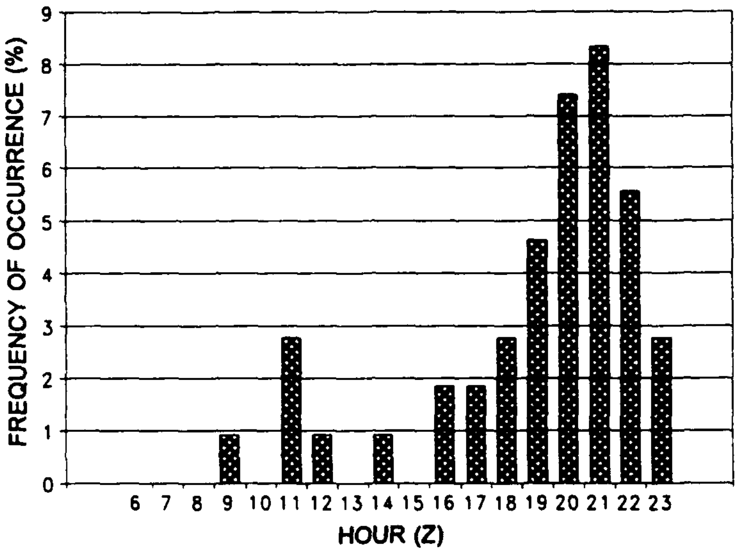


(b)

Figure 3. Frequency of occurrence of at least one lightning strike on Eglin Main during indicated hour for May through September period when upper level winds have a northerly component and lower level winds have a northerly (a), southerly (b) component.



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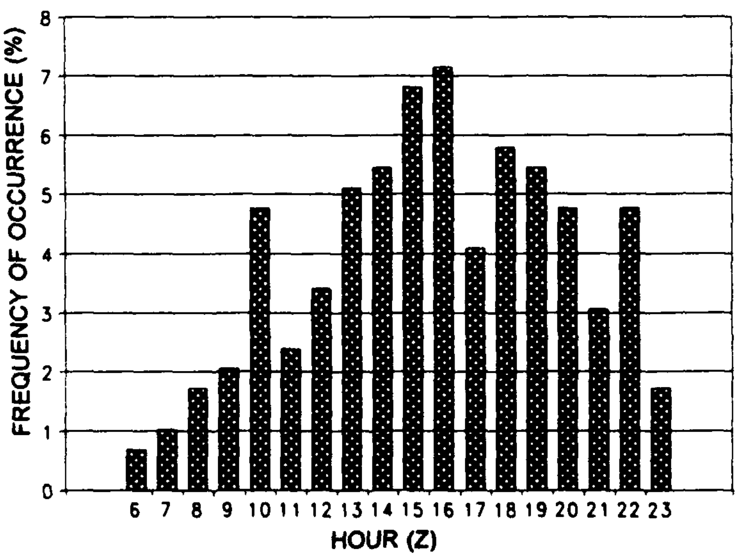
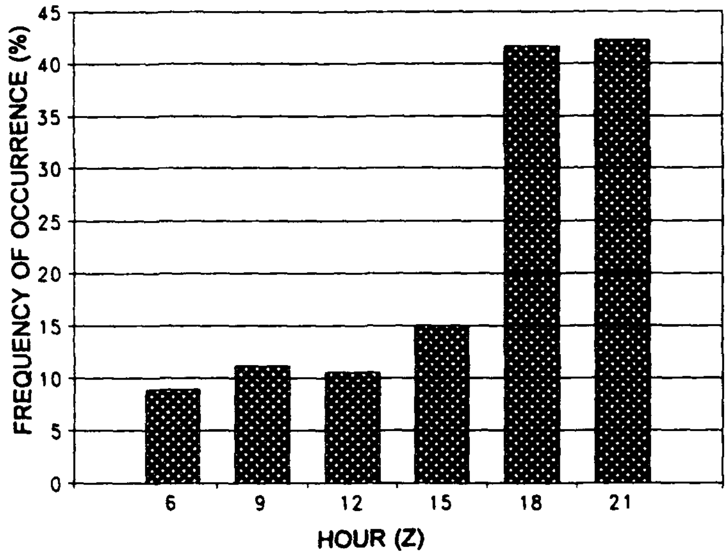


(b)

Figure 4. Frequency of occurrence of at least one lightning strike on Eglin Main during indicated hour for May through September period when upper level winds have a southerly component and lower level winds have a northerly (a), southerly (b) component.



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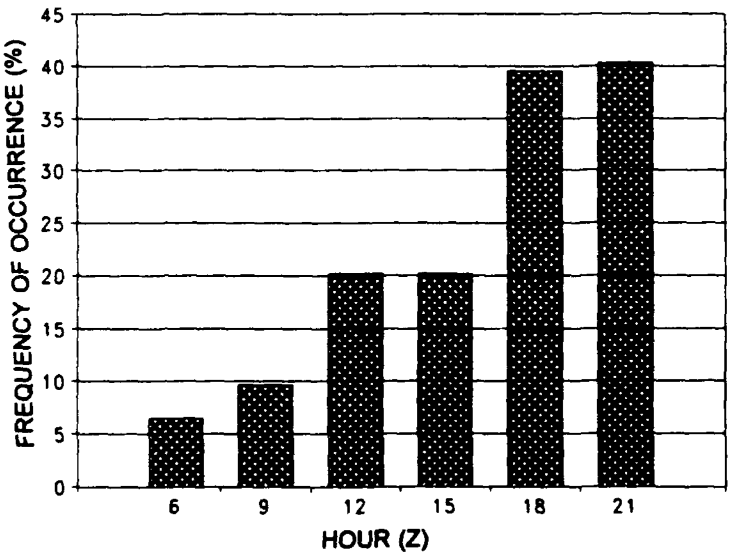
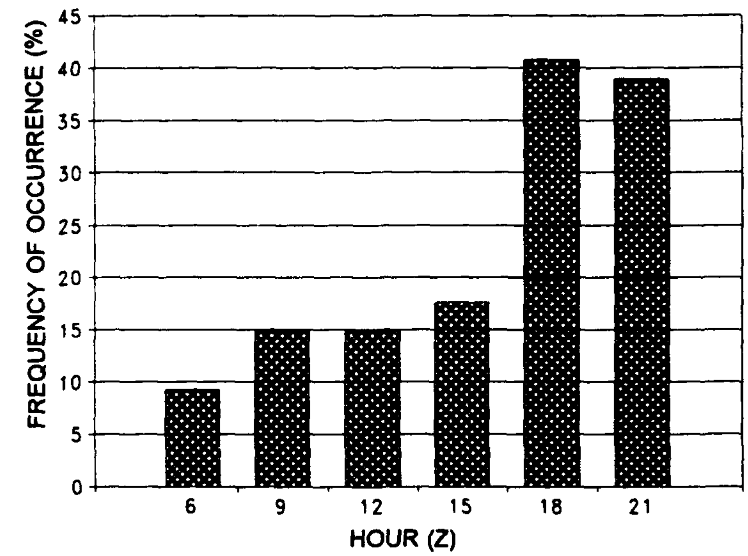


(b)

Figure 5. Frequency of occurrence of at least one lightning strike on Eglin Range during three hour period beginning with indicated hour for May through September period when upper level winds have a northerly component and lower level winds have a northerly (a), southerly (b) component.



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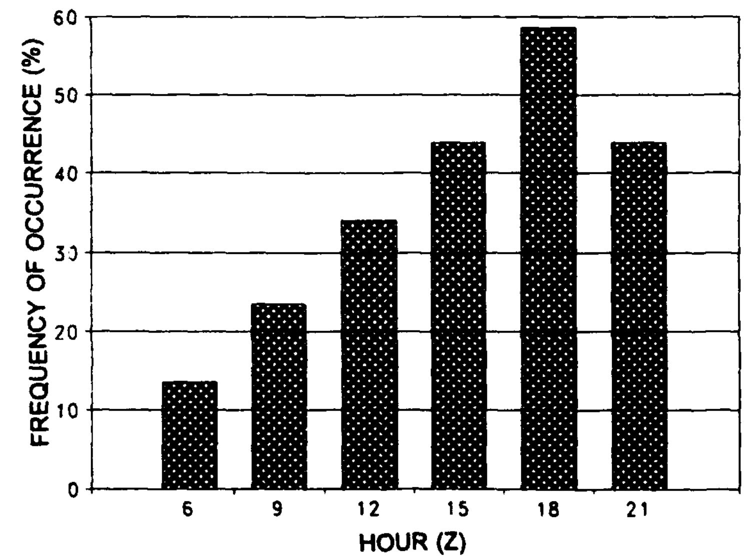

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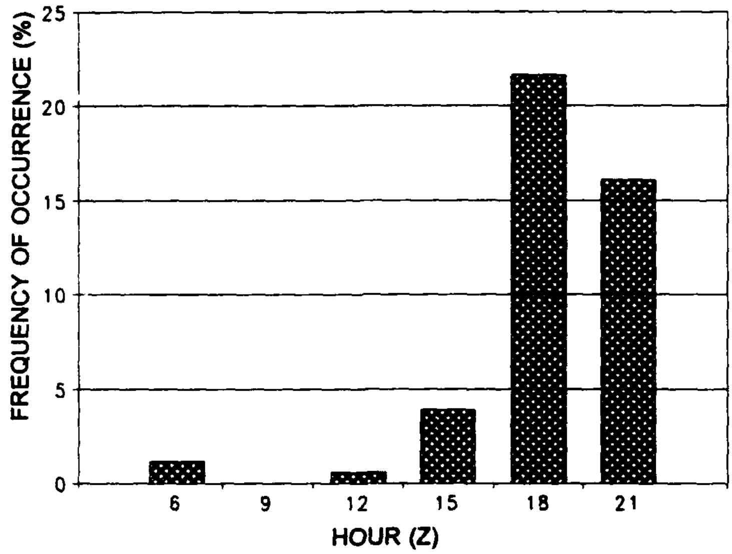
Figure 6. Frequency of occurrence of at least one lightning strike on Eglin Range during three hour period beginning with indicated hour for May through September period when upper level winds have a southerly component and lower level winds have a northerly (a), southerly (b) component.



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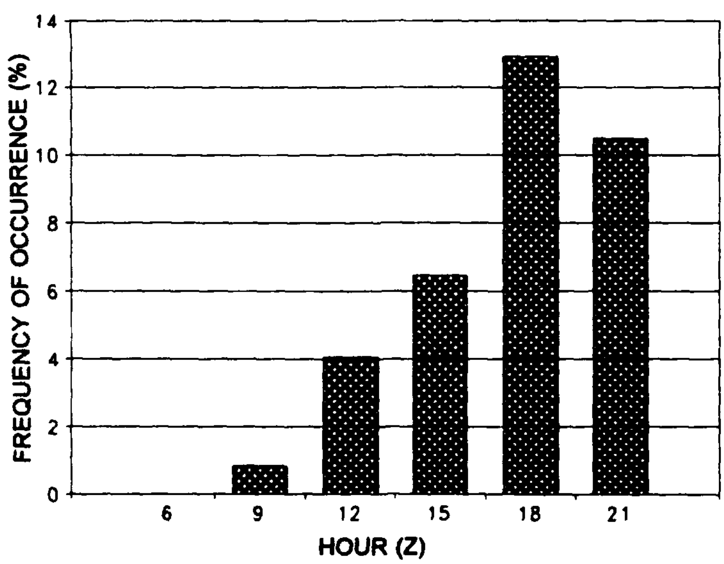
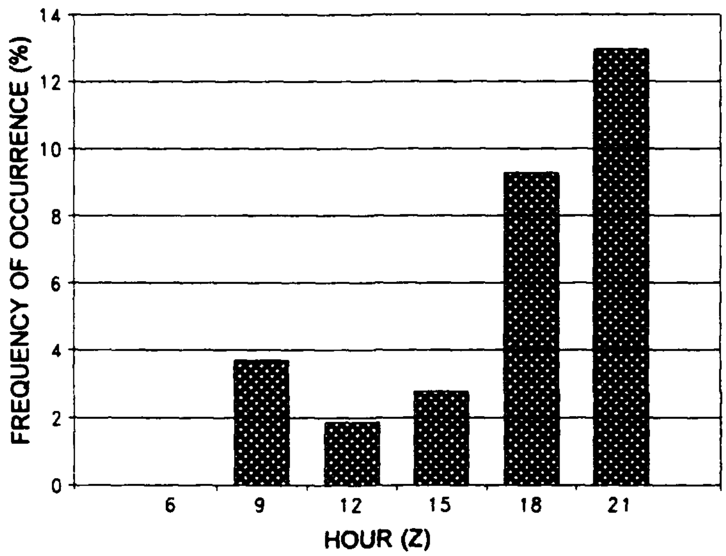


(b)

Figure 7. Frequency of occurrence of at least one lightning strike on Eglin Main during three hour period beginning with indicated hour for May through September period when upper level winds have a northerly component and lower level winds have a northerly (a), southerly (b) component.



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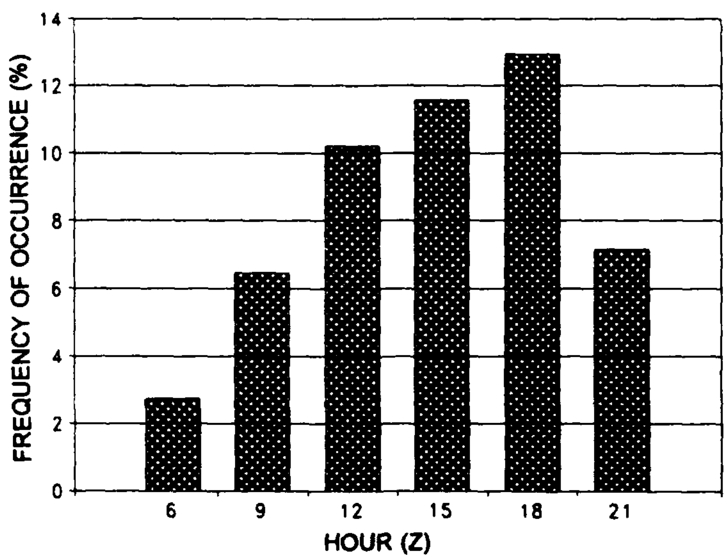

(b)

Figure 8. Frequency of occurrence of at least one lightning strike on Eglin Main during three hour period beginning with indicated hour for May through September period when upper level winds have a southerly component and lower level winds have a northerly (a), southerly (b) component.

3. WINNDEX VALIDATION

3.1 WINNDEX Forecast Procedure. The procedures for forecasting air-mass thunderstorms with WINNDEX are as follows:

- Determine the homogeneity of the air mass across the central Gulf Coast region based on the distributions of temperature and moisture. WINNDEX is valid only when the air mass across this region is homogeneous; the presence of a frontal system or upper-level low precludes the use of the WINNDEX technique.

- Calculate the Showalter Stability Index (SSI) from the 1200Z upper-air sounding. Values greater than or equal to +5°C indicate that the air mass is too stable for thunderstorm development.

- Determine the mean direction of the steering winds between 12,000 and 16,000 feet. Use Figure 9 for southerly (090° - 270°) mean wind directions and use Figure 10 with northerly (275° - 085°) mean wind directions.

- Calculate the convective condensation level (CCL).

- Add the temperature/dew- point spreads ($T - T_d$) at the 700-, 600-, and 500-mb levels.

- If the 2,000-foot wind is *northerly* (270-090°), use the *right side* (b) of Figures 9 & 10 to determine the WINNDEX forecast by the intersection of the CCL and dew point depression sum (DPD).

- If the 2,000-foot wind is *southerly* (090-270°), use the *left side* (a) of Figures 9 & 10 to determine the WINNDEX forecast by the intersection of the CCL and dew point depression sum (DPD).

3.2 Data Sources and Methodology. Inputs to WINNDEX were derived from upper-air DATSAV for Eglin AFB and Apalachicola, FL, from 1 May to 30 September, 1986-1990. Apalachicola upper-air data was used on days for which there was no data for Eglin. Of the 706 12Z soundings available for analysis, 374 (53%) were from Eglin and 332 (47%) were from Apalachicola. The Showalter stability indices were taken directly from USAFETAC's DATSAV database, where they are recorded in whole degrees C. The CCLs were calculated using the method outlined in AWS TR-83-001, *Equations and Algorithms for Meteorological Applications in Air Weather Service,* with one exception: the bottom 50 mb (rather than 100 mb as called for in the technical report) was used to define the moist layer.

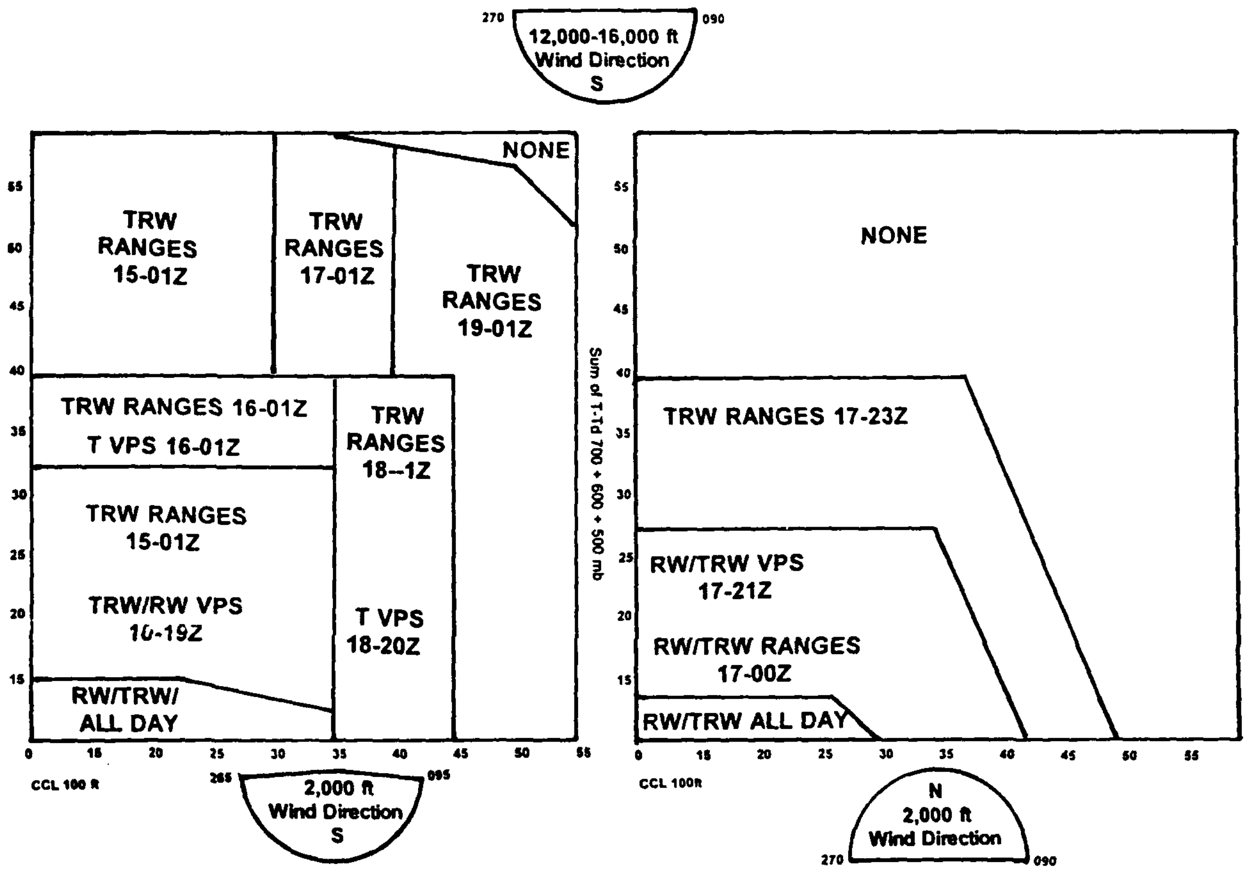

Figure 9. Nomogram used to determine WINNDEX forecast when upper-level winds have a northerly component and lower-level winds have a southerly (a), northerly (b) component.

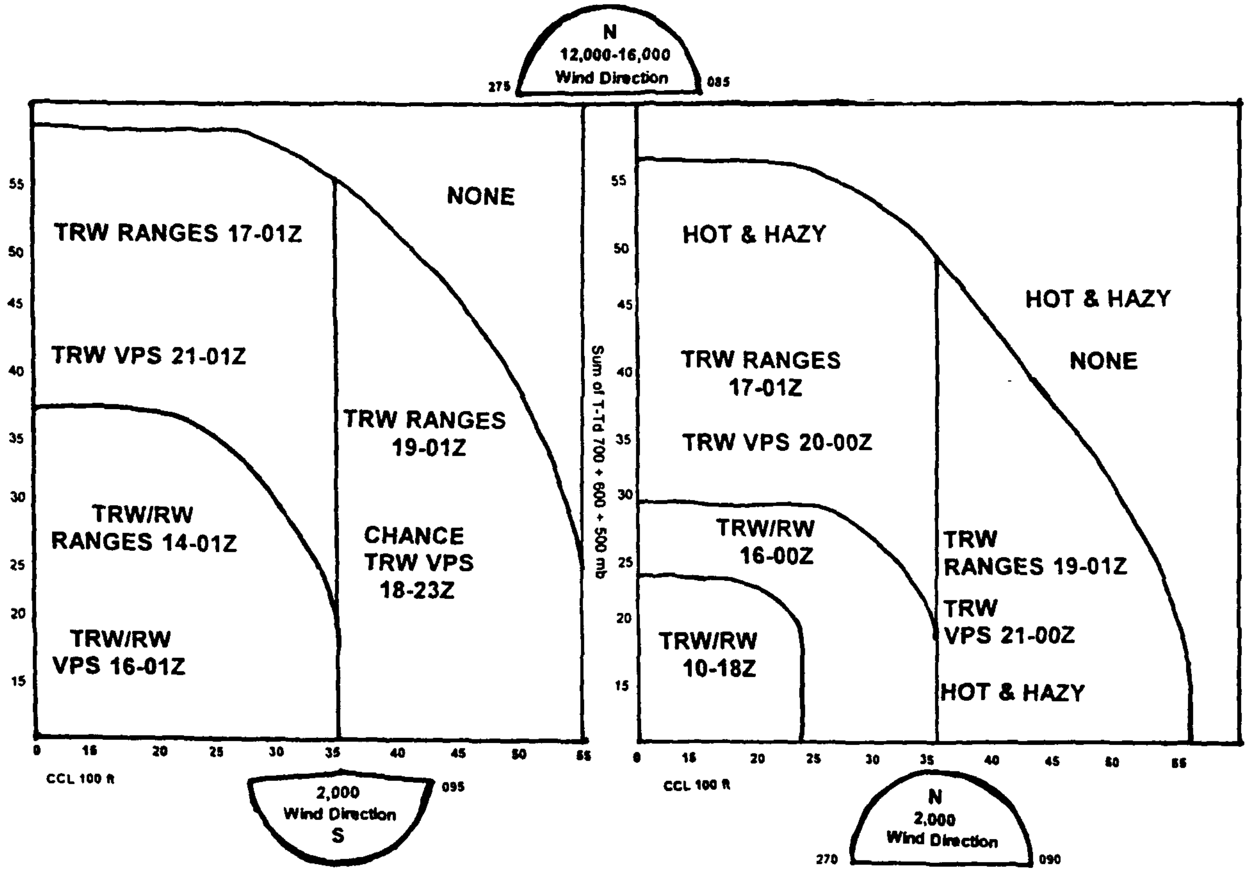

Figure 10. Nomogram used to determine WINNDEX forecast when upper-level winds have a southerly component and lower-level winds have a southerly (a) northerly (b) component.

The WINNDEX was determined for all days in which the Showalter stability index was less than 5. This occurred on 558 (79%) of the 706 days used in the study. As previously agreed upon with the 46th TW/DOW, no attempt was made to exclude days in which use of the WINNDEX would be inappropriate due to the synoptic situation (e.g., a front or upper-level low in the area). It should be noted that when verifying a similar thunderstorm forecasting technique, Forsing (1970) attributed 12% of the unforecast convective activity to the presence of an upper-level trough.

For initial verification purposes, convective activity was said to have occurred on Eglin Main whenever an Eglin surface observation reported rain, rain shower, thunder, or thundershower and/or a lightning strike occurred within 5 nm of 30° 29' N and 86° 32' W.

Verification of the Eglin Range forecast was based on Eglin/Hurlburt surface observations and recorded lightning strikes within an area defined by 30° 45' N, 86° 55' W, and 30° 20' N, 86° 05' W.

Verification was considered in two ways: first, the occurrence or nonoccurrence of convective activity during the day regardless of when it occurred, and second, the *timing* of the activity. Verifications were compared in two ways: those using only lightning data and those using both lightning data and surface observations. For both forecasts and observations, 0600Z was the first hour of the day. Therefore, when the WINNDEX forecast convective activity all day, forecast start time is 0600; only lightning strikes and surface observations at or after this hour were considered for verification.

3.2.1 Skill Scores. For a simple "YES/NO" categorical forecast, we can construct a 2 x 2 contingency table (for example, Table 1) from which several measures of "skill" can be derived. "Percent correct" is simply the number of correct forecasts (YES or NO) expressed as a percentage of the number of forecasts made. The probability of detection (POD) is the number of YES forecasts made expressed as a percentage of the total number of YES events (thunderstorms) observed. The false alarm rate (FAR) is the number of unverified YES forecasts expressed as a percentage of the total number of YES forecasts made. The Heidke skill score (HSS) assesses the skill of a forecast method against that of chance. Because the HSS is "trial dependent" (i.e., any analysis in which the YES and NO events are not equally represented is biased), Hanssen and Kuipers (from Woodcock, 1976) developed the *trial-independent* discriminant "V" score. The HSS and "V" scores range from -1 (no skill) to +1 (perfect skill); zero implies that the forecast method is no better than chance.

TABLE 1. Sample contingency table for YES/NO categorical forecast.

		FORECAST	
		YES	NO
OBSERVED	YES	# of occurrences (A)	# of occurrences (B)
	NO	# of occurrences (C)	# of occurrences (D)

The measures of skill used here to summarize the verification results, defined in terms of the elements of the above contingency table, are:

- Percent Correct -

$$\% \ Correct = \frac{A + D}{A + B + C + D}$$

- Probability of Detection -

$$POD = \frac{A}{A + B}$$

- False Alarm Rate -

$$FAR = \frac{C}{A + C}$$

- Heidke Skill Score -

$$HSS = \frac{2(AD - BC)}{(A + B)(B + D) + (A + C)(C + D)}$$

- Hanssen and Kuipers' discriminant "V" -

$$V = \frac{AD - BC}{[(A + B) * (C + D)]}$$

3.3 Forecast Distribution. Figures 11-14 give the distribution of WINNDEX forecast variables when a lightning strike was recorded on the Eglin Range. Categories are labeled to simplify identification during the presentation of results. Tables 2-5 give the WINNDEX forecast associated with each category, along with the number and perecentage of times this forecast was made based on the total number of days the WINNDEX was determined (i.e., 558).

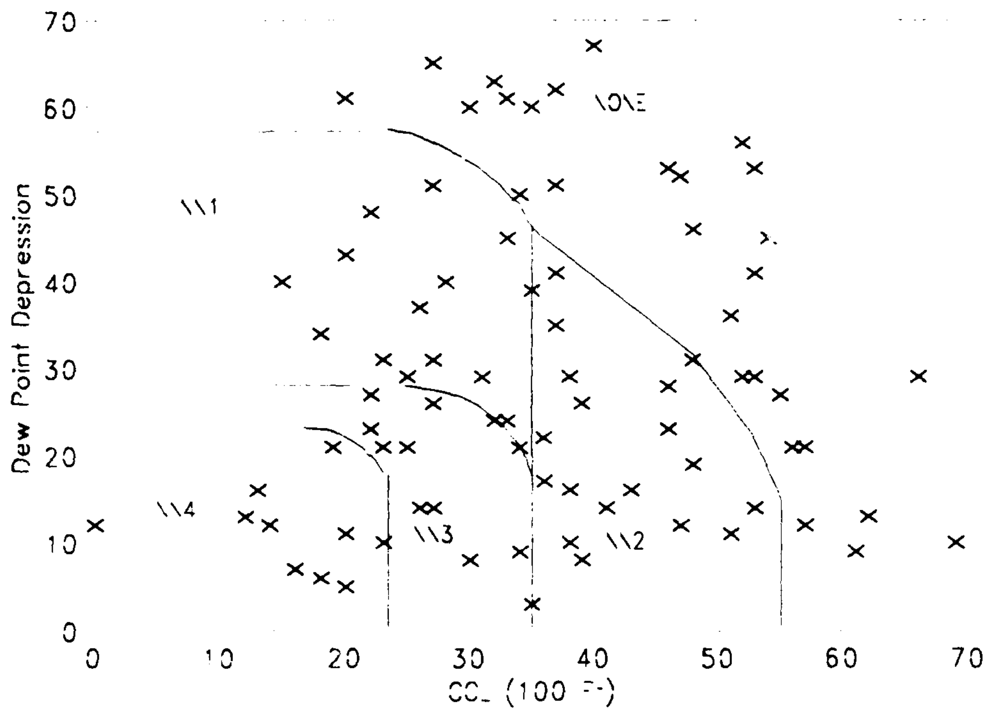

Figure 11. CCL vs DPD for WINNDEX determination when both upper- and lower-level winds have northerly components and a lightning strike was recorded on the Eglin Range.

TABLE 2. WINNDEX forecast categories and their frequency of occurrence when both upper- and lower-level winds have northerly components during the May through September period for the years 1986-1990.

WINNDEX Category	Forecast		Frequency	Percent
	Range	Eglin Main		
NONE	NONE	NONE	52	9
NN1	TRW 17-01Z	TRW 20-00Z	28	5
NN2	TRW 19-01Z	TRW 21-00Z	30	5
NN3	TRW/RW 16-00Z	TRW/RW 16-00Z	14	2
NN4	TRW/RW 10-18Z	TRW/RW 10-18Z	11	2

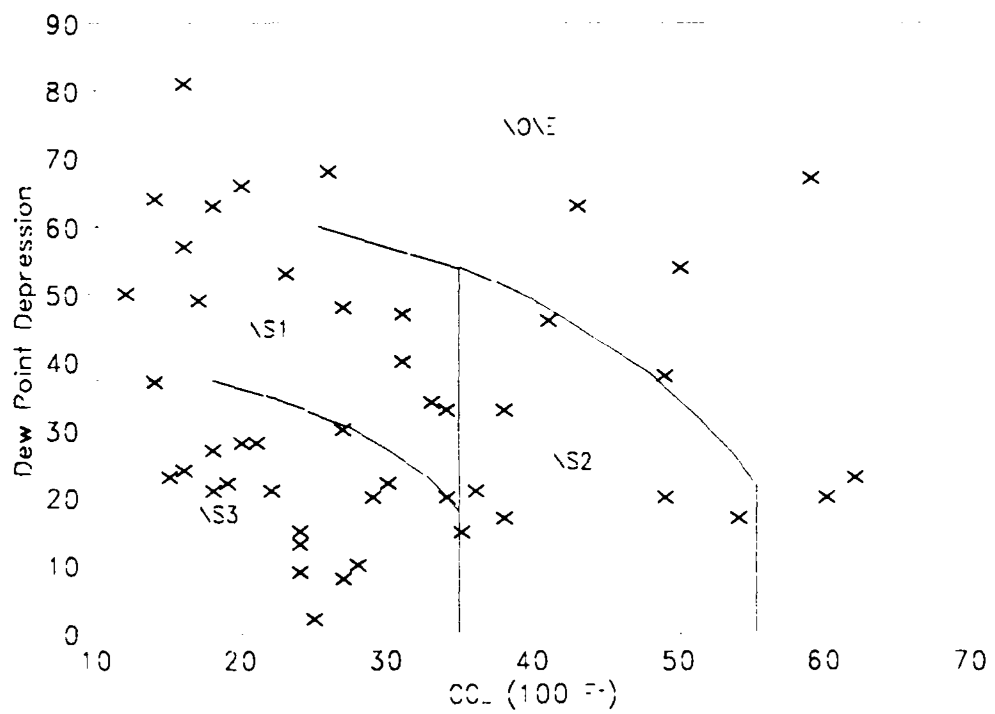

Figure 12 CCL vs DPD for WINNDEX determination when upper-level winds have a northerly component and lower-level winds have a southerly component and a lightning strike was recorded on the Eglin Range.

TABLE 3. WINNDEX forecast categories and their frequency of occurrence when upper-level winds have a northerly component and lower-level winds have a southerly component during the May through September period for the years 1986-1990.

WINNDEX Category	Forecast		Frequency	Percent
	Range	Eglin Main		
NONE	NONE	NONE	30	5
NS1	TRW 17-01Z	TRW 21-00Z	19	3
NS2	TRW 19-01Z	TRW 18-23Z	14	2
NS3	TRW/RW 14-00Z	TRW/RW 16-01Z	28	5

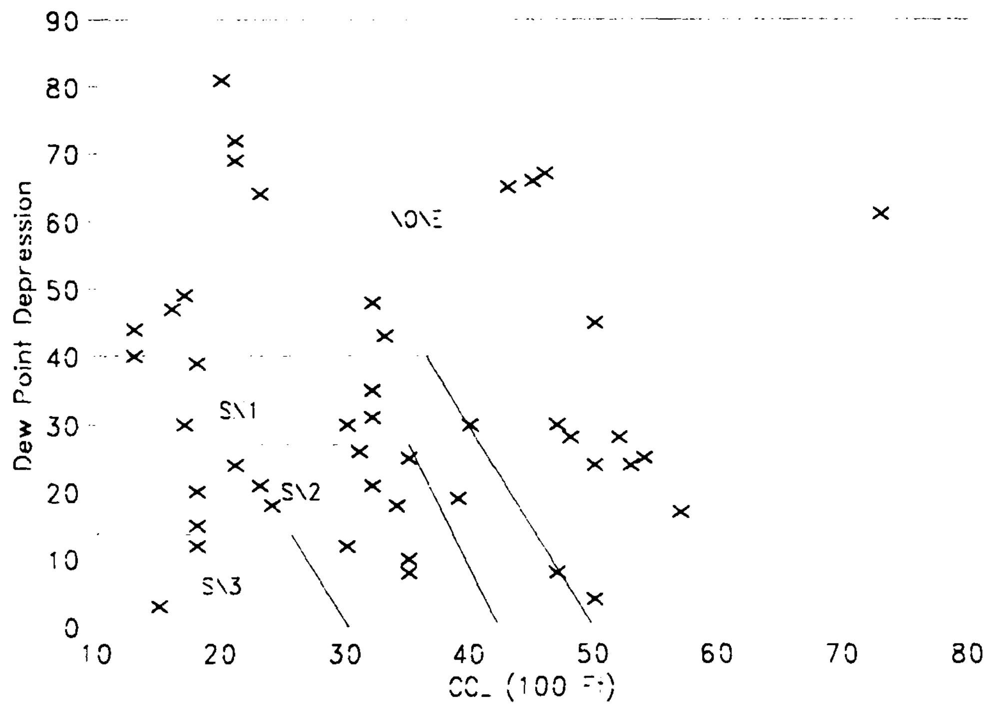

Figure 13 CCL vs DPD for WINNDEX determination when upper-level winds have a southerly component and lower-level winds have a northerly component and a lightning strike was recorded on the Eglin Range.

TABLE 4. WINNDEX forecast categories and their frequency of occurrence when upper-level winds have a southerly component and lower-level winds have a northerly component during the May through September period for the years 1986-1990.

WINNDEX Category	Forecast		Frequency	Percent
	Range	Eglin Main		
NONE	NONE	NONE	42	8
SN1	TRW 17-23Z	NONE	17	3
SN2	RW/TRW 17-00Z	RW/TRW 17-21Z	17	3
SN3	RW/TRW ALL DAY	RW/TRW ALL DAY	6	1

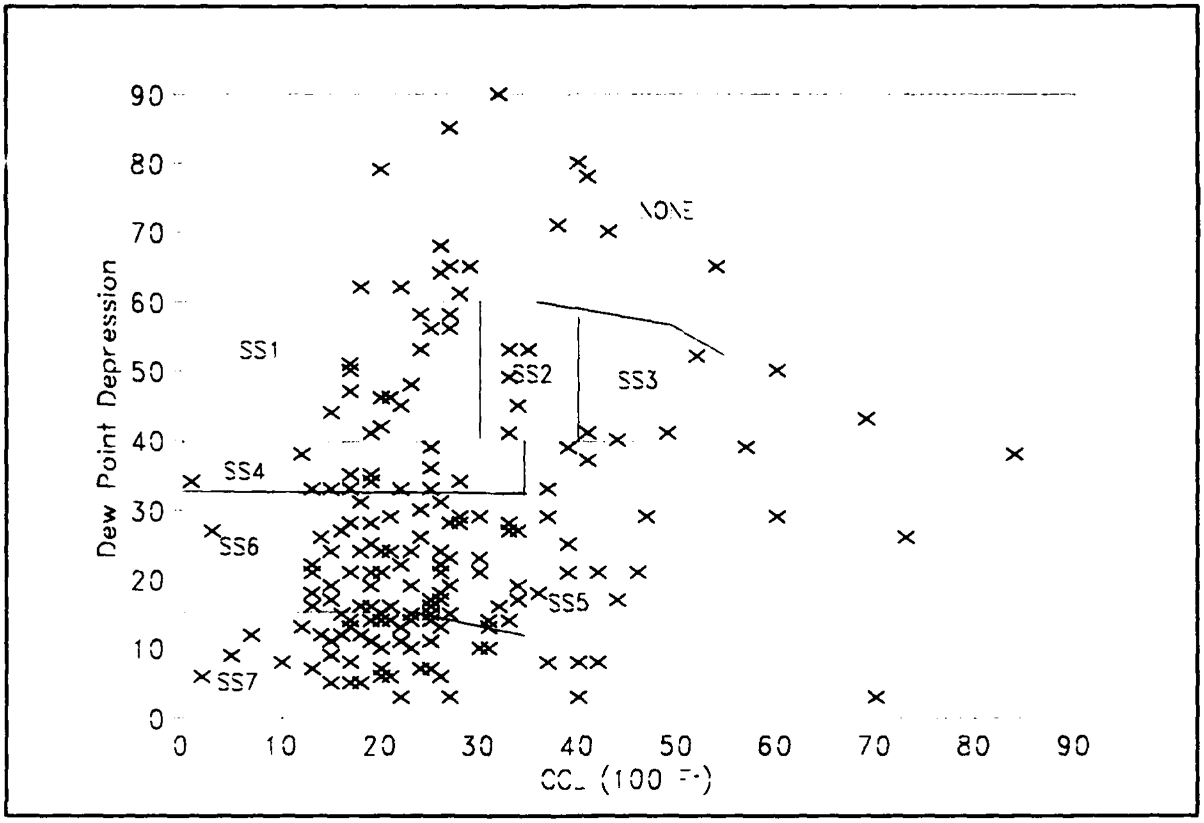

Figure 14 CCL vs DPD for WINNDEX determination when both upper- and lower-level winds have southerly components and a lightning strike was recorded on the Eglin Range.

TABLE 5. WINNDEX forecast categories and their frequency of occurrence when both upper- and lower-level winds have a southerly component during the May through September period for the years 1986-1990.

WINNDEX Category	Forecast		Frequency	Percent
	Range	Eglin Main		
NONE	NONE	NONE	40	7
SS1	TRW 15-01Z	NONE	24	4
SS2	TRW 17-01Z	NONE	8	1
SS3	TRW 19-01Z	NONE	10	2
SS4	TRW 16-01Z	T 16-01Z	21	4
SS5	TRW 18-01Z	T 18-20Z	19	3
SS6	TRW 15-01Z	TRW/RW 10-19Z	71	13
SS7	RW/TRW ALL DAY	RW/TRW ALL DAY	57	10

3.4 Verification. Lightning or a verifiable surface observation was recorded on 41 (28%) and 33 (22%) of the 148 days when the SSI was greater than or equal to five for the Eglin Ranges and Eglin Main respectively. Thunderstorms occurred on 95 (58%)/107 (48%) of the 164/223 days that the WINNDEX forecast no thunderstorm activity for the Eglin Ranges/Eglin Main.

Table 6 gives the number (percentage) of days by category the WINNDEX correctly forecast the occurrence of convective activity and 2) the average time difference between forecasted time of onset of convective activity and the first observed occurrence of convective activity (either lightning strike or surface report).

TABLE 6. Frequency of occurrence of forecasted convective activity and average time difference (Time Diff) between the onset of convective activity and the first observed occurrence of convective activity by category of forecast.

Category	Eglin Range		Eglin Main	
	Frequency (%)	Time Diff (minutes)	Frequency (%)	Time Diff (minutes)
NN1	19 (68)	-38	17 (61)	-146
NN2	22 (73)	-182	21 (70)	-276
NN3	11 (79)	122	10 (71)	110
NN4	11 (100)	274	10 (91)	364
NS1	10 (53)	40	7 (37)	-273
NS2	7 (50)	-130	6 (43)	47
NS3	21 (75)	56	20 (71)	-34
SN1	13 (77)	-83	N/A	N/A
SN2	14 (82)	-148	14 (82)	-58
SN3	3 (50)	418	3 (50)	626
SS1	18 (75)	-97	N/A	N/A
SS2	5 (63)	172	N/A	N/A
SS3	5 (50)	-435	N/A	N/A
SS4	15 (71)	-179	15 (71)	-161
SS5	15 (79)	-284	14 (74)	-239
SS6	66 (93)	-109	59 (83)	196
SS7	55 (97)	330	52 (91)	323

For all days in the study, the PODs for convective activity on the Eglin Range and Eglin Main are 69% and 64%, respectively. The differences between observed and forecast time of first occurrence of convective activity varies widely. Some of the largest differences were associated with the "all day" category. As you'll recall, on these days the beginning of convective activity for both observational and forecast purposes was 0600Z.

Table 7 compares verification results based only on recorded lighting strikes to those using both lightning strikes *and* surfaceobservations. For a large area such as the Eglin Range, there is little difference between verification results using both lightning and surface observations and those just using lightning data. But in a small area such as Eglin Main (100 nm^2) the differences are larger. In both cases, the largest percentage difference between verification results is for the false alarm ratio. Some of the difference is attributed to the fact that not all convective activity will result in lightning, especially during the morning hours. It should also be noted that the locational error associated with the lightning database is between 3 and 6 nm nationwide.

TABLE 7. Percent correct forecast, probability of detection (POD), false alarm rate (FAR), Heidke skill score (HSS) and H&K discriminant 'V' score for WINNDEX YES/NO categorical forecast for Eglin Range and Eglin Main when forecast verified by surface reports and lightning strikes and by lightning strikes alone.

	EGLIN RANGE		EGLIN MAIN	
	Surface Report & Lightning	Lightning only	Surface Report & Lightning	Lightning only
% Correct	68	64	65	56
POD	77	77	70	72
FAR	21	31	26	56
HSS	.21	.18	.26	.17
V	.22	.18	.27	.19

In Tables 6 & 7, a forecast was considered "correct" if convective activity occurred at some point during the day. A more strict verification would consider the forecast correct only when convective activity occurs during the time period specified by the forecast. If the stricter rule is used, however, there is little reduction in the percentage of correct forecasts (1% for Eglin Range and 5% for Eglin Main).

3.5 Conclusion. The WINNDEX showed fair skill in forecasting the occurrence and timing of convective activity. In all 706 days of the study, WINNDEX correctly predicted the occurrence of convective activity 69% of the time on the Eglin range and 64% of the time on Eglin Main. False alarm rates (21% for the Eglin Range and 26% for Eglin Main) were good. However, the mean absolute time difference between the forecast and observed time of the onset of convective activity (as reported in a surface observation or as a recorded lightning strike) was 171 minutes for the Eglin Range and 213 minutes for Eglin Main. Although much of this timing error can be attributed to the "all day" activity commencing much later than the assumed start time of 0600Z, changes in WINNDEX categories may be needed to improve the timing of the technique. For this project, we decided to use a multivariate statistical classification technique called "discriminant analysis" in an attempt to improve thunderstorm forecasting for the Eglin Range and Eglin Main. That technique is described in Section 4.

4. DISCRIMINANT ANALYSIS.

4.1 Introduction. Discriminant Analysis classifies individual observations into groups. It is a supervised classification in that we identify the groups into which we would like our observation classified. In this case, two different classifications will be performed. First, we will classify the observations into 3-hour intervals beginning at 1200Z for the occurrence of the first lightning strike of the day. Second, we provide a YES or NO classification for thunderstorm occurrence for the four 3-hour intervals beginning at 1200Z. In other words, our first analysis will forecast during which 3-hour period the first lightning strike will occur; the second analysis will give a YES/NO forecast for each time period.

4.2 Predictor Variables. The predictor variables used in the discriminant analysis are the Showalter Index (SSI), convective condensation level (CCL), sum of dew-point depressions aloft (DPD) and the level of free convection (PLFC).

4.3 Methodology. The data was divided into dependent and independent data sets. Because of the limited number of lightning strikes during certain hours, the days to be used in the independent dataset could not be selected totally at random; 6 days of the month were selected to make up the independent dataset in such a manner that for low strike counts, about half the strikes would be included in the independent dataset. The dependent data was used to develop the discriminant functions which were then used to classify the independent data. Using the four predictors, the first discriminant analysis predicts during which 3-hour interval the first lightning strike will occur. The second analysis provides a YES/NO classification for thunderstorm activity during the four 3-hour periods beginning at 1200Z. Both analyses are stratified according to upper- and lower-level winds in the same manner as for the WINNDEX. Additionally, only lightning data was used to determine "occurrence" or "nonoccurrence" in the model development and verification processes.

4.4 First Strike Classification. The error matrices associated with the independent classification of the first strike are given in the Appendix. The overall classification accuracy results are given in Table 8.

TABLE 8. Overall classification accuracy (% correct) for classification of first lightning strike on Eglin and Eglin Main, winds as indicated.

Wind category	Eglin Range	Eglin Main
NN	25	28
NS	27	33
SN	42	26
SS	32	34
ALL	31	31

These results indicate the difficulty this model has in classifiying when the first lightning strike is likely to occur. The model may be improved by adding additional predictors (such as time of first strike on the previous day), but this was not attempted. It may very well be that this is the best one can expect when taking only a snapshot of atmospheric conditions (i.e. atmospheric state as depicted in the 1200Z sounding) and not factoring in the change and/or rate of change in atmospheric conditions over time.

4.5 YES/NO Thunderstorm Forecast. In this analysis, the "discriminant" is the surface in four- (the number of predictor variables) dimensional space that separates a "YES" from a "NO" classification. The discriminant model returns a value between 0 and 1 which relates to the distance the point lies from the discriminant. Points on the discriminant return a value of 0.50 and are associated with a small degree of classification certainty; points farther from the discriminant return values approaching either zero or one, indicating greater confidence in a YES (1) or NO (0) classification. To the first order, the values returned from the discriminant can be interpreted as an estimate of the probability of thunderstorms. The independent classification results are presented in Tables 9 & 10.

TABLE 9. Percent correct classification, probability of detection (POD), false alarm rate (FAR), Heidke skill score (HSS), and V discriminant skill score for predicting whether a thunderstorm will occur on the Eglin Range during a 3-hour period beginning with the indicated hour when upper- and lower-level winds are as indicated. For the Eglin Range, the overall POD of thunderstorms is very good at 88% but the FAR is high at 52%. The numbers are similar for Eglin Main.

Winds	Hour (Z)	% Correct	POD (%)	FAR (%)	HSS	V
NN	1200	79	100	50	.54	.73
NN	1500	67	100	55	.39	.54
NN	1800	79	94	29	.58	.58
NN	2100	73	82	30	.45	.45
NS	1200	45	80	79	.08	.18
NS	1500	55	88	63	.21	.30
NS	1800	59	80	56	.23	.27
NS	2100	48	67	67	.05	.07
SN	1200	70	100	53	.44	.60
SN	1500	70	100	62	.39	.64
SN	1800	63	75	44	.27	.28
SN	2100	56	60	57	.12	.13
SS	1200	55	93	63	.23	.35
SS	1500	63	88	46	.29	.31
SS	1800	70	90	35	.38	.38
SS	2100	61	100	55	.32	.42
ALL	ALL	63	88	52	.32	.38

TABLE 10. Percent correct classification, probability of detection (POD), false alarm rate (FAR), Heidke skill score (HSS), and V discriminant skill score for predicting whether a thunderstorm will occur on Eglin Main during a 3-hour period beginning with the indicated hour when upper- and lower-level winds are as indicated.

Winds	Hour (Z)	% Correct	POD (%)	FAR (%)	HSS	V
NN	1200	71	N/A	100	N/A	N/A
NN	1500	75	100	86	.19	.74
NN	1800	58	88	73	.21	.40
NN	2100	58	100	74	.23	.51
NS	1200	96	100	33	.78	.95
NS	1500	71	100	78	.26	.68
NS	1800	75	60	67	.38	.71
NS	2100	54	100	75	.08	.13
SN	1200	74	100	86	.19	.73
SN	1500	100	100	0	1.00	1.00
SN	1800	48	100	80	.15	.40
SN	2100	57	100	71	.24	.47
SS	1200	68	78	74	.24	.44
SS	1500	49	67	89	.04	.13
SS	1800	44	80	90	.05	.21
SS	2100	62	75	89	.09	.36
ALL	ALL	63	85	81	.18	.46

One measure of the goodness of a probability forecast is the Brier Score (BS) (Brier, 1950). The Brier Score ranges from zero (or perfect forecasting) to one (for no-skill forecasting). In turn, we can compare the BS of a forecast model to some reference standard such as climatology or persistence.

Murphy and Winkler (1982) developed the Brier Skill Score (BSS) to make this comparison. The BSS gives the percentage increase or decrease in the Brier Score of one forecast method from the reference standard. The equations for the Brier Score and Brier Skill Score are:

$$BS = \frac{1}{2n} \sum_{j=1}^{r} \sum_{i=1}^{n} (F_{ij} - E_{ij})^2$$

$$BSS = \left[1 - \left(\frac{\sum_{j=1}^{r} \sum_{i=1}^{n} (F_{ij} - E_{ij})^2}{\sum_{j=1}^{r} \sum_{i=1}^{n} (R_{ij} - E_{ij})^2} \right) \right] \times 100\%$$

where for n occasions, an event can occur in only one of r possible classes; F_{ij}, *is forecast probability,* R_{ij} is *reference standard probability,* and E_{ij} is *event probability* (0 or 1). Brier scores and Brier skill scores are presented in Table 11.

Typically, the model has a difficult time beating persistence and climatology. The Brier scores are low, however, considering that the number of YES cases for model development (dependent dataset) and verification (independent dataset) were low (<5) in many cases.

TABLE 11. Brier scores (BS) of discriminant analysis forecast model and Brier skill scores (BSS) for this model compared to persistence (Pers) and climatology (Climo) for indicated upper- and lower-level winds and 3-hour time periods beginning with stated hour (Z).

		Eglin Range			Eglin Main		
Wnd	Hr	BS	BSS vs Climo	BSS vs Pers	BS	BSS vs Climo	BSS vs Pers
NN	12	.18	-2	-19	.17	-	-
NN	15	.20	6	17	.19	-367	-124
NN	18	.15	41	-23	.29	-103	-15
NN	21	.16	37	24	.26	-107	-24
NS	12	.35	-147	-3	.03	65	78
NS	15	.29	-39	17	.18	-141	-48
NS	18	.28	-24	18	.22	-100	-75
NS	21	.26	-17	16	.23	-33	-12
SN	12	.24	-16	-7	.21	-403	-388
SN	15	.24	-56	9	0	100	100
SN	18	.26	-6	21	.37	-221	-323
SN	21	.30	-30	-17	.30	-102	25
SS	12	.29	-43	-7	.25	-114	-53
SS	15	.23	5	31	.30	-265	-188
SS	18	.20	-20	37	.29	-313	-100
SS	21	.24	-4	25	.23	-305	-155

To estimate of the probability of thunderstorm activity during any of the four 3-hour periods, you would (1) calculate intermediate YES and NO terms using the coefficients in Tables A-9 and A-10 of the Appendix, and (2) substitute these terms into the following formula:

$$Prob\ (YES) = \frac{1}{\exp(NO - YES) + 1}$$

As an example, if both the upper- and lower-level winds are out of the north and we want to know the probability of thunderstorms on the Eglin Range during the 3-hour period beginning at 1200Z given that SSI = 1, DPD = 30, C C L = 1,500 feet, and PLFC = 700. The YES and NO terms are then:

YES = -7.38479 - .14193*SSI + .07543*DPD + .0889*CCL + .0144*PLFC

YES = -7.38479 - .14193*1 + .07543*30 + .0889*15 + .0144*700 = 6.14968

NO = -8.26849 - .10262*1 + .10407*30 + .09454*15 + .01379*700 = 5.82209

Therefore:

$$Prob\ (YES) = \frac{1}{\exp(5.82209 - 6.14968) + 1} = .5811$$

With a probability of > .50 then,, thunderstorms should be forecast for the 3-hour period beginning at 1200Z.

4.5 Conclusion. The attempt to determine the first 3-hour period in which lightning would occur was not very successful; the overall correct classification was only 31%. Additional predictors and an increased period of record to increase the number of occurrences of lightning may improve the predictive ability of this technique. Although a direct comparison of WINNDEX skill and the discriminate model's ability to predict thunderstorms in a 3-hour period may not be justified, we can say that the discriminant model had a Heidke skill score of .32 compared to .18 for WINNDEX. The discriminant model had a higher probability of detection (88% vs 69%) but the false alarm ratio was much worse (54% vs 31%). Here too, additional predictors or more "training" data may improve the accuracy of the model.

APPENDIX

TABLE A-1. Error matrix for independent classification of occurrence/nonoccurrence of first lightning strike on **Eglin Range** when both upper and lower-level winds have a northerly component. Overall classification accuracy is 25%.

		PREDICTED						
		None	AM	1200	1500	1800	2100	Total
OBSERVED	None	13	1	3	2	2	7	28
	Am	0	0	0	2	1	0	3
	1200	0	0	0	0	1	0	1
	1500	0	0	2	0	0	1	3
	1800	1	3	5	8	1	3	21
	2100	0	3	0	0	1	1	5
	Total	14	7	10	12	6	12	61

TABLE A-2. Error matrix for independent classification of occurrence/nonoccurrence of first lightning strike on **Eglin Range** when upper-level winds have a northerly component and lower-level winds have a southerly component. Overall classification accuracy is 27%.

		PREDICTED						
		None	AM	1200	1500	1800	2100	Total
OBSERVED	None	10	4	3	4	6	0	27
	AM	0	0	1	1	1	0	3
	1200	1	0	0	2	1	0	4
	1500	0	3	0	1	1	0	5
	1800	0	3	1	0	2	0	6
	2100	0	2	0	0	1	0	3
	Total	11	12	5	8	12	0	48

TABLE A-3. Error matrix for independent classification of occurrence/nonoccurrence of first lightning strike on **Eglin Range** when upper-level winds have a southerly component and lower-level winds have a northerly component. Overall classification accuracy is 42%.

		PREDICTED						
		None	AM	1200	1500	1800	2100	Total
OBSERVED	None	9	3	0	0	3	3	18
	AM	0	1	0	0	2	0	3
	1200	1	0	0	0	0	0	1
	1500	0	3	0	0	0	1	4
	1800	0	2	0	0	5	1	8
	2100	0	0	0	0	2	1	4
	Total	10	10	0	0	12	6	38

TABLE A-4. Error matrix for independent classification of occurrence/nonoccurrence of first lightning strike on **Eglin Range** when both upper- and lower-level winds have a southerly component. Overall classification accuracy is 32%.

		PREDICTED						
		None	AM	1200	1500	1800	2100	Total
OBSERVED	None	13	2	3	4	9	6	37
	AM	2	5	8	1	0	3	19
	1200	0	1	8	0	0	2	11
	1500	1	2	4	2	1	5	15
	1800	1	2	2	0	2	2	9
	2100	1	1	0	0	1	0	3
	Total	18	13	25	7	13	18	94

TABLE A-5. Error matrix for independent classification of occurrence/nonoccurrence of first lightning strike on **Eglin Main** when both upper- and lower-level winds have a northerly component. Overall classification accuracy is 28%.

		PREDICTED						
		None	AM	1200	1500	1800	2100	Total
OBSERVED	None	17	7	4	12	5	10	55
	AM	0	0	0	1	0	0	1
	1200	0	0	0	0	0	0	0
	1500	0	0	1	2	0	0	3
	1800	0	2	2	1	1	2	8
	2100	1	0	0	3	1	0	5
	Total	18	9	7	19	7	12	72

TABLE A-6. Error matrix for independent classification of occurrence/nonoccurrence of first lightning strike on **Eglin Main** when upper-level winds have a northerly component and lower-level winds have a southerly component. Overall classification accuracy is 33%.

		PREDICTED						
		None	AM	1200	1500	1800	2100	Total
OBSERVED	None	10	3	0	3	5	4	25
	AM	0	0	0	0	0	0	0
	1200	0	0	0	0	2	0	2
	1500	0	0	0	1	2	0	3
	1800	0	0	0	1	1	0	2
	2100	0	1	0	2	1	0	4
	Total	10	4	0	7	11	4	36

TABLE A-7. Error matrix for independent classification of occurrence/nonoccurrence of first lightning strike on **Eglin Main** when upper-level winds have a southerly component and lower-level winds have a northerly component. Overall classification accuracy is 26%.

		PREDICTED						
		None	AM	1200	1500	1800	2100	Total
OBSERVED	None	8	6	4	7	4	2	31
	AM	1	0	0	0	1	0	2
	1200	0	0	0	0	0	0	0
	1500	0	1	0	0	0	0	1
	1800	0	1	1	1	1	0	4
	2100	1	0	0	0	2	2	5
	Total	10	8	5	8	8	4	43

TABLE A-8. Error matrix for independent classification of occurrence/nonoccurrence of first lightning strike on **Eglin Main** when both upper- and lower-level winds have a southerly component. Overall classification accuracy is 34%.

		PREDICTED						
		None	AM	1200	1500	1800	2100	Total
OBSERVED	None	28	7	14	6	12	6	73
	AM	1	0	4	1	3	0	9
	1200	0	1	6	1	1	1	10
	1500	2	1	1	1	1	2	8
	1800	2	1	1	1	3	0	8
	2100	1	0	3	0	1	0	5
	Total	38	6	28	8	25	8	113

TABLE A9. Coefficients of linear discriminant function for YES/NO categorical forecast of thunderstorm activity on the **Eglin Range** during 3-hour period beginning with specified hour (Z).

		YES					NO				
Wind	Hour	Int	SW	DPD	CCL	PLFC	Int	SW	DPD	CCL	PLFC
NN	12	-7.38479	-.14193	.07543	.0889	.0144	-8.26849	-.10262	.10407	.09454	.01379
	15	-7.55814	-.15313	.08299	.08886	.01438	-8.27043	-.09595	.10322	.09492	.01375
	18	-8.23791	-.17058	.08569	.09302	.01512	-8.21934	-.06548	.10717	.09353	.01300
	21	-8.02663	-.14086	.08592	.09311	.01472	-8.32914	-.07467	.10962	.09350	.01313
NS	12	-8.92189	-.10215	.08102	.20464	.01301	-9.16082	-.05871	.10262	.21518	.01145
	15	-8.53485	-.07535	.08425	.20033	.01245	-9.28923	-.06792	.10321	.21848	.01157
	18	-8.44797	-.09937	.08984	.20960	.01194	-10.03761	.01117	.11641	.22008	.01167
	21	-8.30989	-.07650	.09609	.21152	.01182	-10.91210	.07974	.11414	.23270	.01300
SN	12	-6.83171	.05704	.04570	.09757	.01214	-6.45367	.05473	.05574	.10979	.01033
	15	-5.80461	.04095	.04491	.09380	.01094	-6.78752	.06223	.05926	.11551	.01038
	18	-7.34018	-.07472	.05686	.11558	.01198	-6.20014	.08284	.05388	.10658	.01026
	21	-6.90260	-.01557	.05470	.10860	.01152	-6.31615	.08103	.05430	.10801	.01022
SS	12	-8.91195	.20290	.06160	.18950	.01561	-10.70352	.44304	.08966	.19923	.01588
	15	-9.22821	.23209	.06233	.18611	.01591	-10.44211	.37202	.08750	.20683	.01518
	18	-9.37842	.24150	.06714	.18905	.01579	-10.42910	.40555	.08124	.20568	.01531
	21	-9.18893	.21537	.06825	.18910	.01560	-10.35090	.41785	.07420	.20040	.01591

TABLE A10. Coefficients of linear discriminant function for YES/NO categorical forecast of thunderstorm activity on **Eglin Main** during 3-hour period begining with specified hour (Z).

		YES					NO				
Wind	Hour	Int	SW	DPD	CCL	PLFC	Int	SW	DPD	CCL	PLFC
NN	12	-7.47497	-.01553	.06898	.06908	.01518	-8.06785	-.11251	.09823	.09364	.01390
	15	-9.47678	-.19940	.12027	.08079	.01568	-8.03359	-.11110	.09781	.09332	.01392
	18	-8.40665	-.17390	.07763	.09968	.01532	-8.07116	-.09434	.10325	.09160	.01355
	21	-8.88778	-.23190	.09240	.10234	.01537	-7.98022	-.10158	.09826	.09259	.01381
NS	12	-8.54669	.03615	.06936	.19202	.01296	-9.08860	-.07914	.09904	.21400	.01178
	15	-8.58714	-.17211	.08089	.20957	.01253	-9.10417	-.05777	.09878	.21268	.01179
	18	-9.97774	-.15685	.07456	.23019	.01391	-8.98184	-.06446	.09833	.21111	.01173
	21	-8.53148	-.08882	.08968	.20174	.01214	-9.12470	-.06676	.09822	.21446	.01182
SN	12	-3.45686	.02584	.04926	.06480	.00807	-6.67461	.05789	.05491	.11241	.01081
	15	-7.79159	.12852	.07187	.07696	.01254	-6.45238	.05430	.05423	.10849	.01055
	18	-6.07964	.00574	.03989	.10022	.01127	-6.55730	.06389	.05702	.10960	.01044
	21	-7.22469	-.14735	.05618	.11566	.01161	-6.41871	.07163	.05426	.10756	.01048
SS	12	-9.10868	.16771	.04538	.19390	.01603	-9.77838	.29907	.07560	.19207	.01561
	15	-8.51084	.19325	.04966	.18738	.01538	-9.97350	.30631	.07789	.19436	.01581
	18	-9.74489	.16860	.06383	.20077	.01604	-9.62978	.28964	.07086	.19123	.01564
	21	-8.25816	.10377	.05812	.18447	.01497	-9.87898	.31497	.07279	.19428	.01586

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ACRINABs

ACRINAB	Acronym, initialism, or abbreviation
BS	Brier Score
BSS	Brier Skill Score
CCL	Convective Condensation Level
DATSAV	Data Save
DPD	Dew-Point Depression Sum
FAR	False Alarm Ratio
HSS	Heidke Skill Score
NN	Northerly upper- and lower-level winds per WINNDEX definition
NS	Northerly upper- and southerly lower-level winds per WINNDEX definition
PLFC	Pressure of Level of Free Convection
POD	Probility of Detection
Prob	Probability
RW	Rain shower
SN	Southerly upper- and northerly lower-level winds per WINNDEX definition
SS	Southerly upper- and lower-level winds per WINNDEX definition
SSI	Showalter Stability Index
TRW	Thunderstorm
V	Hanssen and Kuipers' Discriminant Score
WINNDEX	Thunderstorm Forecasting Technique Developed by Mr Roger Winn

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HQUSSPACECOM/J3W, 250 S. Peterson Blvd, STE 317, Bldg 1, Stop 7, Peterson AFB, CO 80914-3230	1
USAFA/DFP, Attn: Capt Paul Bellaire, Colorado Springs, CO 80840-5701	1
AFMC/DOW, Bldg 266, Post 108P Chidlaw Rd.,Wright-Patterson AFB, OH 45433-5001	1
FASTC/TAW, 4115 Hebble Creek Rd., Ste 33, Wright-Patterson AFB, OH 45433-5637	1
ASD/WE, Bldg 91, 3rd St, Wright-Patterson AFB, OH 45433-6503	1
AFIT/CIR, Wright-Patterson AFB, OH 45433-6583	1
WL/DOA, Wright-Patterson AFB, OH 45433-6543	1
WL/DOW, Wright Patterson AFB, OH 45433-6543	1
645 WS/CC, Wright-Patterson AFB, OH 45433-5000	1
46 TG/WE, Holloman AFB, NM 88330-5000	1
PL/WE, Kirtland AFB, NM 87117-5000	1
HQ AFOTEC/WE, Kirtland AFB, NM 87117-7001	1
RL/WE, Griffiss AFB, NY 13441-5700	1
ROME LAB/SUL,Corridor W, Ste 262, 26 Electronic Pkwy, Griffiss AFB, NY 13441-4514	1
AFCESA/WE, Tyndall AFB, FL 32403-5000	1
325 OSS/OSW, Florida Ave., Stop 22, Bldg 149, Tyndall AFB, IL 32403-5048	1
AFESC/RDXT, Bldg 1120, Stop 21, Tyndall AFB, FL 32403-5000	1
ESD/WE, Vandenberg Dr., Bldg 1624, Hanscom AFB, MA 01731-5000	1
PL/T[illegible]L, Research Library, Hanscom AFB, MA 01731-5000	1
PL/GP, Hansom AFB, MA 01731-5000	1
3246 TW/DOW, Bldg 60, Rm 60, Eglin AFB FL 32542-5000	3
46 WS/CC, Eglin AFB,FL 31542-5000	1
AFFTC/WE, Edwards AFB, CA 93523-5000	1
SMC/SDW, PO Box 92960, Bldg 117, El Segundo, Los Angeles AFB, CA 90009-2960	1
UTTR/WE, Hill AFB, UT 84056-5000	1
USAFA/CWOSW, Air Field Dr., Bldg 9206, USAF Academy, CO 80840-5000	1
USCENTCOM/CCJ3-W, Bldg 540, MacDill Blvd, MacDill AFB, FL 33608-7001	1
ESMC/WE, Patrick AFB, FL 32925-5000	1
OL-A, AFCOS, Site R, Fort Ritchie, MD 21719-5010	1
USAFALCENT RA, Pope AFB, NC 28308-5000	1
CCSO/FL, Tinker AFB, OK 73145-6340	1
AFOSR/NL, Bolling AFB, DC 20332-5000	1
TFWC/WE, Nellis AFB, NV 89191-5000	1
SMC, Det 2/TDO, Onizuka AFB CA 94088-3430	1
AL/OEBE, 2402 East Drive, Brooks AFB, TX 78235-5114	1
1 SOW/OGSW, 150 Bennett, Bldg 90730, Hurlburt Fld FL 32544-5000	1
HQ AFSOC/DOW, Bldg 1, Hurlburt Fld FL 32544-5000	1
AMC/XOWR, Bldg P40 N, 402 Scott Dr,. Rm 132, Scott AFB, IL 62225-5363	1
ATC/DOTW, 244 F Street East, Suite #3, Randolph AFB, TX 78150-4325	1
PACAF/DOW, Bldg 1102, Hickam AFB, HI 96853-5000	1
USSTRATCOM/J3615, Rm L127, Bldg 522, 901 SAC Blvd, Offutt AFB, NE 68113-5000	1
USCENTCOM/J3-W, MacDill AFB FL 33608-7001	1
USSOCCENT/SOCJ2-SWO, 7115 S Boundary Dr, MacDill AFB FL 33621-5101	1
USSOCOM/SOJ3-W, MacDill AFB FL 33608-6001	1
ACC/DOW, Bldg 21, 30 Elm St, Ste 215, Langley AFB, VA 23655-2093	1
1 WXG, Bldg 168, Hardee Stm Ft McPherson GA 30300-5000	1
24WS, Unit 0640, APO AA 34001-5000	1

9 COS/AOSW, Bldg 1130, Shaw Dr., Shaw AFB, SC 29152-5410	1
1TSI/CDW, US Army Intel, Ft Huachuca AI, AZ 85613-5000	1
1 WXG, Bldg 168, Hardee St., Ft McPherson, GA 30300-5000	1
JSOC/Weather, P.O. Box 70239, Ft Bragg, NC 28307-5000	1
USAFE/DOW, Unit 3050, Box 15, APO AE 09094-5015	1
USAFE/DOWO, Unit 3050, Box 500, APO AE 09094-5015	1
17AF/DOW, Unit 4065, APO AE 09136-5000	1
HQ USEUCOM ECJ3, Unit 30400, Box 1000, APO AE 09128-4209	1
7WS, CINCUSAREUR/AREAWX, APO AE 09403-5000	1
Army Training and Doctrine Command, ATDO-IW (ATTN: SWO), Ft Monroe VA 23651-5000	1
COMNAVOCEANCOM, Code N312, Stennis Space Ctr, MS 39529-5000	2
COMNAVOCEANCOM (Capt Brown, Code N332), Stennis Space Ctr, MS 39529-5001	1
NAVOCEANO (Ba[illegible]ie Rau), Bldg 8100, Rm 203D, Stennis Space Ctr, MS 39522-5001	2
NAVOCEANO, Code 9220 (Tony Ortolano), Stennis Space Ctr, MS 39529-5001	1
Maury Oceanographic Library, Naval Oceanography Office, Stennis Space Ctr, MS 39522-5001	1
Naval Research Laboratory, Monterey, CA 93943-5006	1
Naval Research Laboratory, Code 4323, Washington, DC 20375	1
Naval Research Laboratory (Dr Riley), Code 4180, Washington, DC 20375 (SESS reports)	1
Naval Postgraduate School, Chmn, Dept of Meteorology, Code 63, Monterey, CA 93943-5000	1
Chief, APG Met Team, Bldg 1134, Attn: AMSTE-TC-AM CAB, Aberdeen Proving Ground, MD 21005-5001	1
Atmospheric Sciences Laboratory (SLCAS-AS-I 3 10-2c), White Sands Missile Range, NM 88002-5501	1
TECOM Atmos Sci Div, AMSTE-TC-AA (MacBlain), White Sands Missile Range, NM 88002-5504	1
White Sands Met Team, AMSTE-TC-AM (WS), White Sands Missile Range, NM 88002-5501	1
USA TECOM, ATTN: AMSTE-TC-AM (RE) TECOM Met Team, Redstone Arsenal, AL 35898-8052	1
Director, U.S.A.-CETEC, Attn: GL-AE (Whitmarsh), Fort Belvoir, VA 22060-5546	1
Technical Library, Dugway Proving Ground, Dugway, UT 84022-5000	1
NOAA/MASC Library MC5, 325 Broadway, Boulder, CO 80303-3328	2
NOAA Library-EOC4W5C4, Attn: ACQ, 6009 Executive Blvd, Rockville, MD 20852	1
NOAA/NESDIS (Attn: Nancy Everson, E/RA22), World Weather Bldg, Rm 703, Washington, DC 20233	1
NGDC, NOAA, Mail Code E/GC4, 325 Broadway, Boulder, CO 80333-3328	1
NWS W/OSD, Bldg SSM C-2 East-West Hwy, Silver Spring, MD 20910	1
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AWSTL, Bldg 859 Buchanan St, Scott AFB IL 62225-5118	25